Chapter 11

Pelvis: Sacrum, Coccyx, and Os Coxae

Just as the bony structure joining the front limbs to the trunk is called the shoulder girdle, so is the bony complex joining the hind limbs to the trunk called the pelvic girdle. The pelvic girdles of terrestrial vertebrates are connected to the vertebral column and are much larger than their homologs in fish. These adaptations are required for weight-bearing and muscle attachment in the terrestrial forms. In early land-dwelling vertebrates, the right and left limb girdles joined dorsally with the sacral vertebrae to form a bony ring around the rear of the trunk. This is still the basic form in the tetrapod pelvis.

The adult human pelvis is composed of four complex elements: the right and left **ossa coxa** (singular: **os coxae**) and the **sacrum** and **coccyx**. The sacrum and coccyx are part of the axial skeleton and are actually variably fused vertebrae. Each **os coxae** represents a fusion of three primitive elements: **ilium**, **ischium**, and **pubis**.

The bony pelvis functions to support and protect the abdominal and pelvic organs. In addition, it anchors muscles of the abdomen and leg. Unlike the shoulder girdle, which is a movable platform, the pelvic girdle is firmly fixed to the axial skeleton via its vertebral element, the sacrum.

11.1 Sacrum (Figures 11.1–11.5)

11.1.1 Anatomy

The sacral vertebrae fuse during adolescence into one immobile, wedge-shaped bone, the sacrum. This bone is typically formed from five segments, but may have as few as four or as many as six. The sacrum is located at the base of the vertebral column. It articulates bilaterally with the two ossa coxa and inferiorly with the small coccyx.

a. The **base** of the sacrum is the broad anterosuperior surface of the bone, comprising the tops of both alae and the plateau of the first sacral vertebra.
b. The **sacral plateau** is the broad, flat, anterosuperiorly inclined surface of the first sacral centrum that articulates with the terminal, or most inferior, lumbar vertebra (normally L-5).
c. The **sacral promontory** is the anterior midline projection of the sacral plateau.
d. The **alae**, or "wings," are those parts of the first sacral element that sweep laterally from the centrum. Each **ala** articulates laterally with the posteromedial surface of an os coxae.

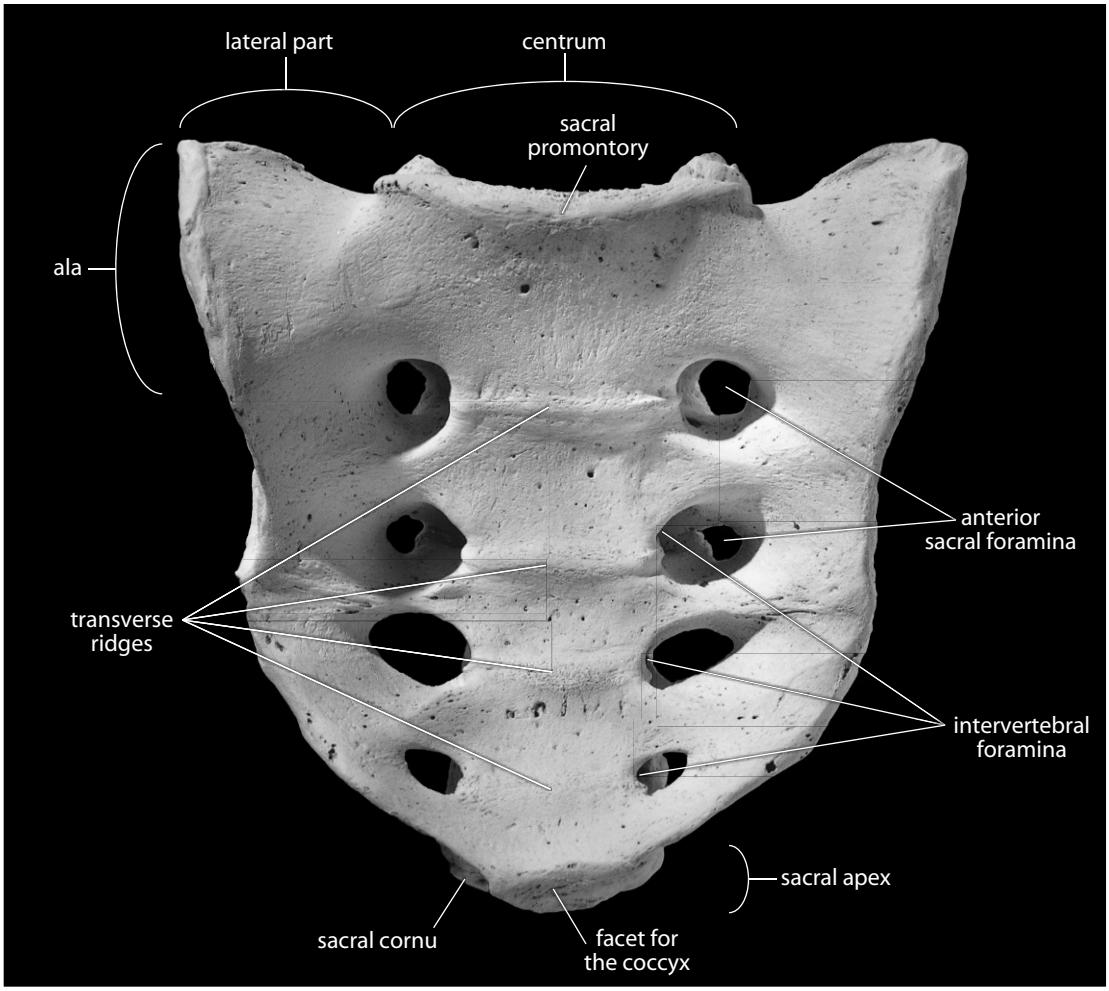

Figure 11.1 **Sacrum, anteroinferior view.** Natural size.

e. The **sacral canal** is in inferior continuation of the vertebral canal.

f. The **pelvic surface** is the smooth, concave surface of the sacrum that faces the pelvic canal.

g. The **transverse ridges** (or **lines**) along the pelvic surface mark the lines of fusion of the sacral vertebrae.

h. The **auricular surface** forms the sacral contribution to the articulation between the sacrum and the os coxae (the **sacroiliac joint**). The sacroiliac articulation is the least mobile synovial joint in the body. The auricular ("ear-shaped") surface of the sacrum articulates with the auricular surface of the os coxae. The sacral auricular surface is best seen in lateral aspect.

i. The **sacral tuberosity** is the roughened, irregular, nonarticular area behind the auricular surface. The tuberosity is the sacral attachment site of the *sacroiliac ligaments*.

j. The **lateral part** (or **mass**) of the sacrum is the part of the bone formed by the expanded transverse processes and the vestiges of the sacral ribs. The lateral part includes the auricular surface, the ala, and the sacral tuberosity.

k. The **anterior** (or **pelvic**) **sacral foramina** are openings in the concave anterior surface of the sacrum through which the *anterior divisions of the sacral nerves* and the *lateral sacral arteries* pass.

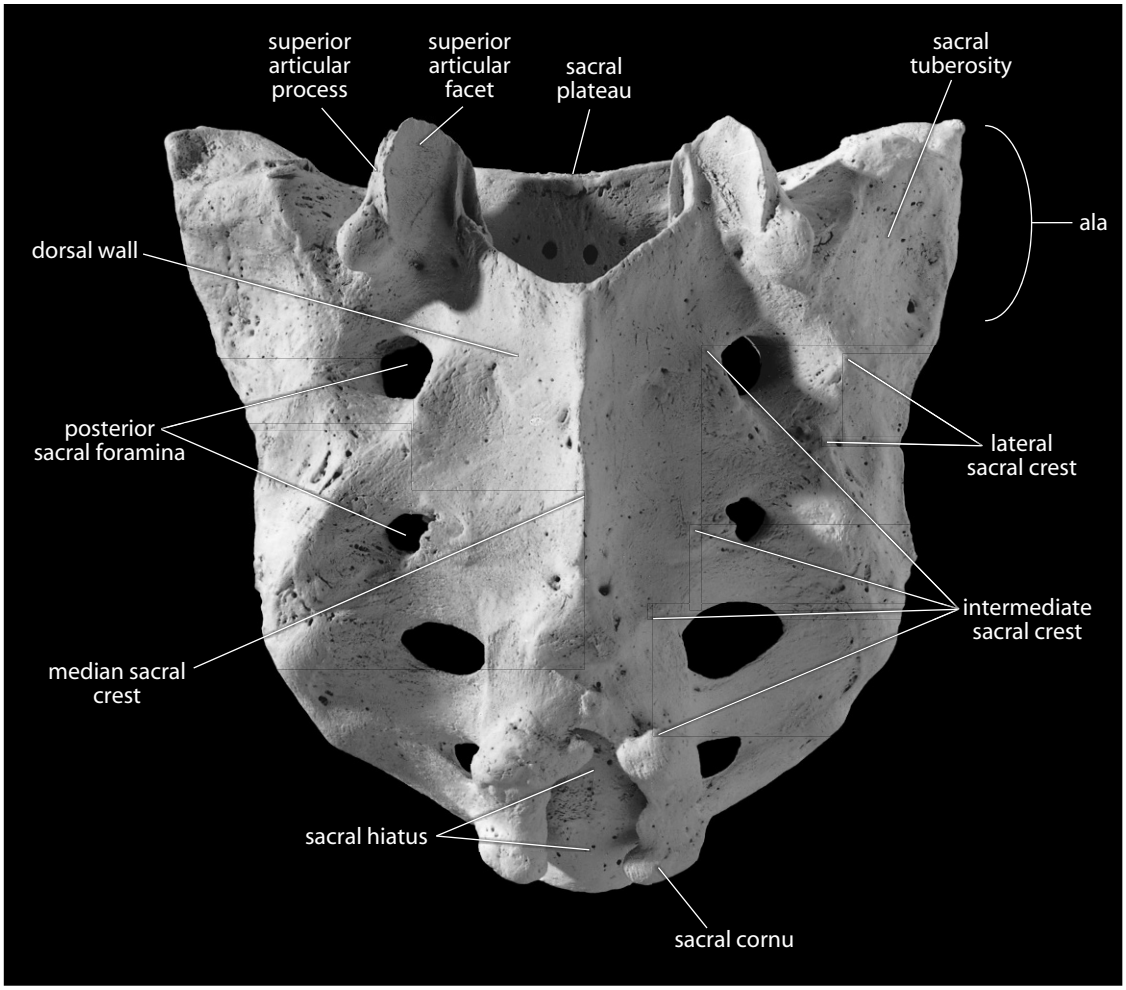

Figure 11.2 **Sacrum, posterosuperior view.** Natural size

l. The **superior articular facets** of the sacrum articulate with facets on the inferior articular processes of the most inferior lumbar vertebra.

m. The **superior articular processes** extend superiorly from the dorsal wall to accommodate the superior articular facets.

n. The **dorsal surface** is the rough, convex, posterior-facing surface of the sacrum.

o. The **dorsal wall** of the sacrum is a rough, irregular, variable plate of bone composed of the ossified laminae and articular processes of the fused sacral vertebrae.

p. The **posterior** (or **dorsal**) **sacral foramina** are openings in the convex posterior surface of the sacrum through which the *posterior divisions of the sacral nerves* pass.

q. The **intervertebral foramina** are formed by fused superior and inferior notches. These foramina are internal to and medial to both anterior and posterior sacral foramina.

r. The **median sacral crest** (or **sacral spine**) is the highly variable midline projection of the dorsal wall formed from the fused spinous processes of the sacral vertebrae.

s. The **intermediate sacral crest** is formed by the fused remnants of the sacral articular processes, and is located just medial to the posterior sacral foramina.

t. The **lateral sacral crest** is formed by the fused remnants of the sacral transverse processes, and is located just lateral to the posterior sacral foramina.

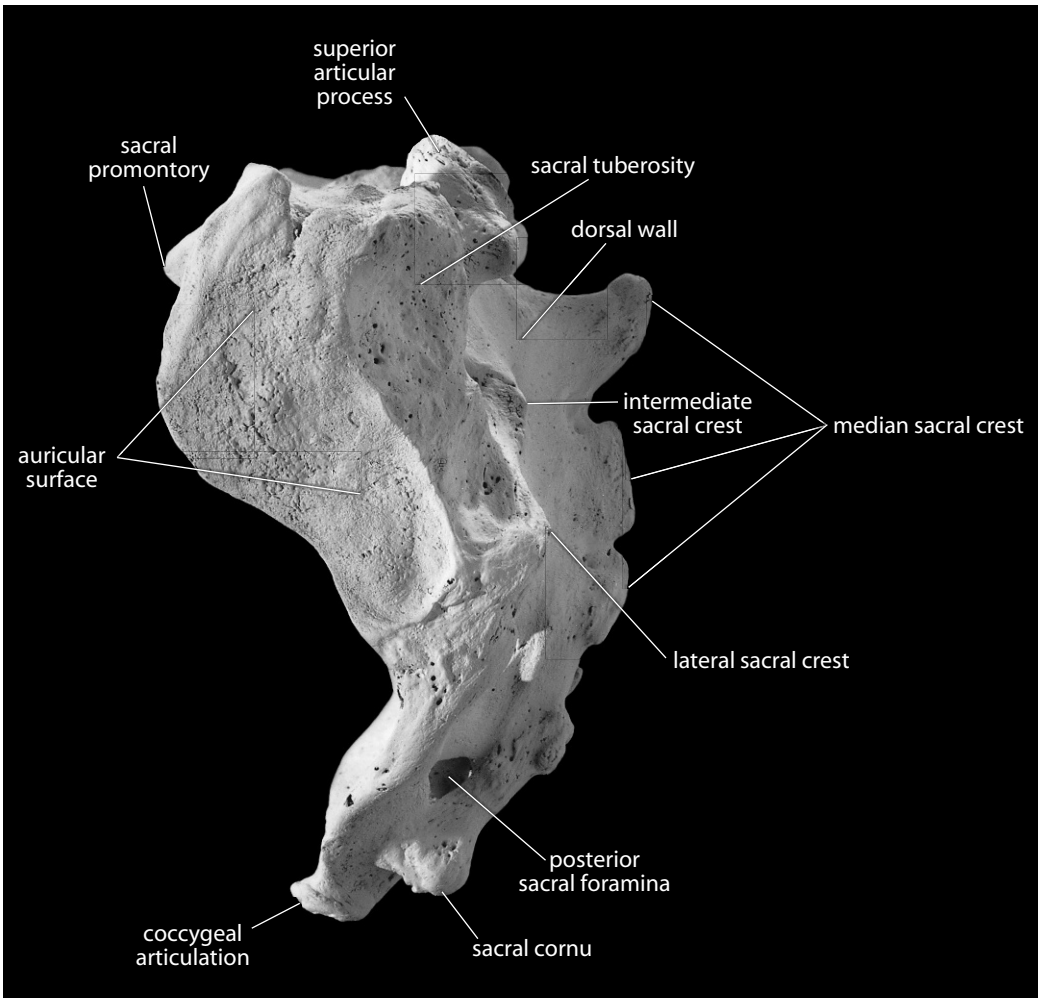

Figure 11.3 **Sacrum, left lateral.** Anterior is toward the left. Natural size.

u. The **sacral hiatus** refers to the area usually limited to S-4 and S-5, where the dorsal wall is missing.

v. The **sacral cornua** (or sacral horns; singular: **cornu**) are two small processes that extend inferiorly from either side of the sacral hiatus.

w. The **apex of the sacrum** is the narrow, inferior tip of the sacrum that includes the articular facet for the coccyx.

x. The **facet for the coccyx** comprises the inferior surface of the last sacral vertebra.

11.1.2 Growth (Figure 6.5)

The sacrum ossifies from approximately 21 separate centers in individuals with five sacral vertebrae (although Scheuer and Black (2000) note that this number is highly variable and should be expected to differ between individuals). As with the more cranial vertebrae, each sacral segment has an ossification center in the centrum and two additional centers: one forming each half of the neural arch. Additionally, S-1 through S-3 (or sometimes S-4) have two additional anterolateral

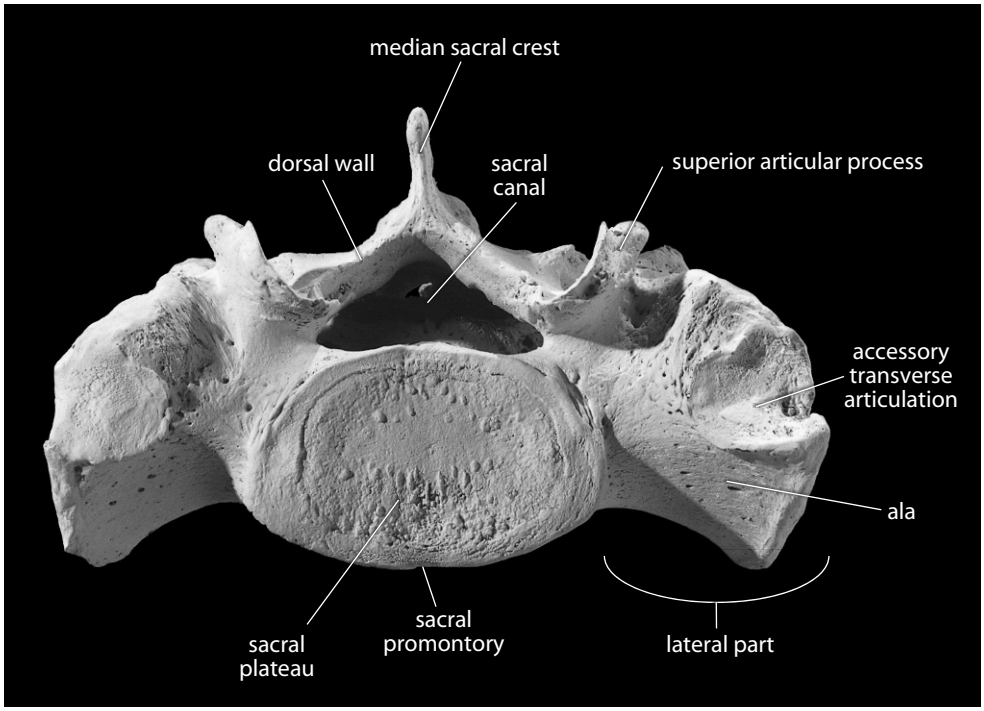

Figure 11.4 **Sacrum, anterosuperior view.** Posterior is up. Note the laterally placed facets for the sacralized L-5 of this individual. Natural size.

centers of ossification that are derived from incorporated costal elements. Additionally, two epiphyseal plates form at each sacroiliac articular region, one forming the auricular surface and one forming the lateral margin inferior to this.

11.1.3 Possible Confusion

- A fragmentary promontory region might be mistaken for a lumbar vertebra. Lumbar vertebrae, however, lack attached alae.
- The sacral auricular surface might be mistaken for the coxal auricular surface in a fragmentary or broken os coxae. However, the sacral auricular surface has virtually no adjacent outer bone surface surrounding it as the os coxae does.

11.1.4 Siding

When fragmentary, parts of the sacrum can be sided as follows:

- The anterior sacral surface is smooth and concave, with transverse ridges.
- The size of sacral vertebrae diminishes inferiorly.
- The auricular surface is lateral, and the apex of this V-shaped feature is anterior.

11.1.5 Sacral Measurements (Figure 11.5)

1. **Maximum anterior height** (or **ventral height**) (Martin, 1928: 1001, #2): Place the stationary jaw of the sliding caliper on the ventral midline point of the sacral promontory, and then extend the other jaw to the midline of the inferoventral midline point of the last sacral vertebral body.
2. **Maximum anterior breadth** (Martin, 1928: 1000, #5; Flander, 1978: 104): Use a sliding caliper to determine the greatest breadth of the first sacral vertebra (including the alae).
3. **Ventral height arc** (Martin, 1928: 1001, #1): Using a flexible cloth tape, measure the surface distance from the ventral midline point of S-1 (the sacral promontory) to the inferoventral midline point of the S-5 body.

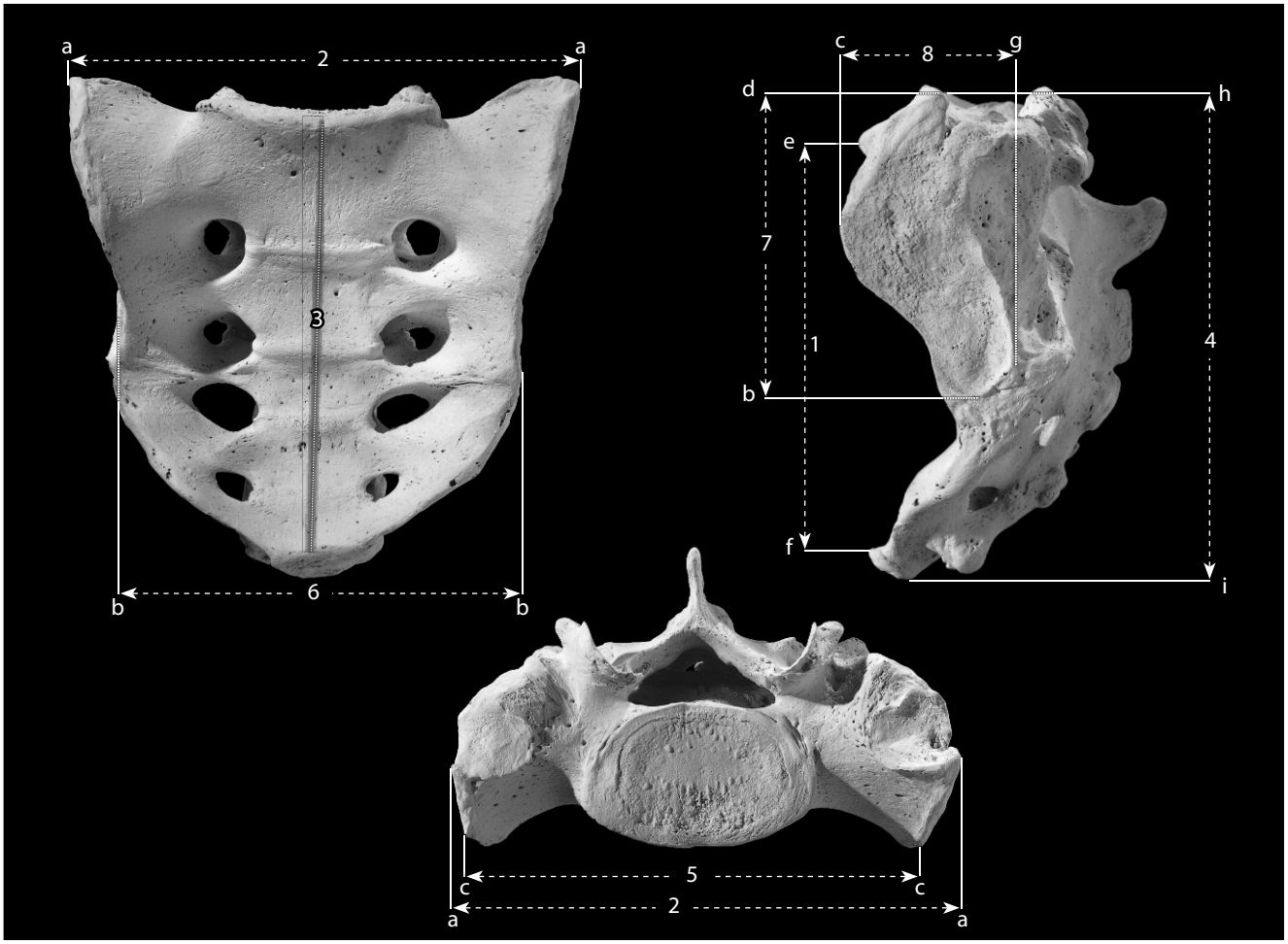

Figure 11.5 **Sacral measurements.** Two-thirds natural size.

Locations: a) most lateral point of S-1 ala; b) inferiormost point of auricular surface; c) most superoventral point of auricular surface; d) superiormost point of auricular surface; e) midline point of sacral promontory; f) inferoventral midline point of last sacral body; g) dorsalmost point of auricular surface; h) superodorsal midline point of S-1 body; i) inferodorsal midline point of S-5 body.

Measurements: 1) maximum anterior height; 2) maximum anterior breadth; 3) ventral arc; 4) dorsal height; 5) anterosuperior breadth; 6) middle breadth; 7) auricular surface height; 8) auricular surface breadth.

4. **Dorsal height** (Martin, 1928: 1001, #3; Buikstra and Ubelaker, 1994: 81, #53): Using a sliding caliper, measure the distance from the superodorsal midline point of the S-1 body to the inferodorsal midline point of the S-5 body.
5. **Anterosuperior breadth** (Martin, 1928: 1001, #5; Buikstra and Ubelaker, 1994: 81, #54): Using a sliding caliper, measure the transverse distance between the most superoventral points of the auricular margins.
6. **Middle breadth** (Martin, 1928: 1001, #9): Using a sliding caliper, measure the transverse distance between the inferiormost points of the auricular margins.
7. **Auricular surface height** (Martin, 1928: 1002, #14): Using a sliding caliper, determine the maximum craniocaudal dimension of the auricular surface.
8. **Auricular surface breadth** (Martin, 1928: 1002, #15): Using a sliding caliper, determine the maximum dorsoventral dimension of the auricular surface.
9. **Sacral index** (Hrdlička, 1939): (maximum anterior breadth ÷ maximum anterior height) × 100.

11.1.6 Sacral Nonmetric Traits

- **Number of sacral vertebrae**: The number of sacral vertebrae can vary due to sacralization of the last lumbar vertebra or of the first coccygeal vertebra.
- **Expanded sacral hiatus**: The sacral hiatus is normally formed by the failure of the lamina of S-5 (and sometimes S-4) to unite dorsally. Note the cranialmost extent of the sacral hiatus. If the hiatus occurs more cranially than S-3, the condition is referred to as an **expanded sacral hiatus**. If the hiatus extends above S-1, the condition is called **spina bifida**.
- **Accessory transverse articulations**: Articular surfaces on the anterosuperior alae for the transverse processes of a (usually sacralized) L-5 (Figure 6.12). The sacrum used to illustrate this chapter has bilateral transverse articulations (most visible in Figure 11.4). These accessory transverse articulations should not be confused with the accessory iliac articulations located posterosuperior to the auricular surface (Section 11.3.6).

11.2 Coccyx (Figure 11.6)

11.2.1 Anatomy

The coccyx, the vestigial tail, is highly variable in shape, with three to five (most often four) variably fused segments. The rudimentary vertebrae of the coccyx have articular and transverse processes superiorly, but they lack pedicles, laminae, and spinous processes. The sacral articulation is via the superior surface of the first coccygeal body (Cx-1) as well as a relatively large pair of tubercles called the **coccygeal cornua** (Figure 11.6). The cornua (singular: **cornu**) are rudimentary articular processes that contact the sacrum via the sacral cornua. The coccyx may fuse with the sacrum late in life.

As with the sacrum, the individual vertebral elements of the coccyx decrease in size inferiorly, and horizontal lines of fusion can be seen between adjacent coccygeal vertebrae. The coccyx serves to anchor pelvic muscles and ligaments.

a. The **coccygeal cornua** are the vestiges of superior articular facets.
b. The most lateral portions of the first coccygeal vertebra (Cx-1) are rudimentary **transverse processes**.

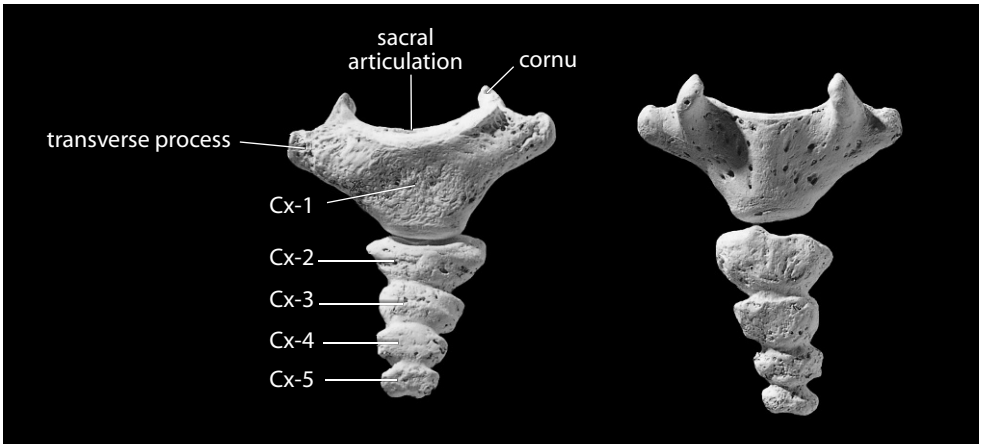

Figure 11.6 **Coccyx.** *Left:* anterior view; *right:* posterior view. Superior is up. Natural size.

11.2.2 Coccygeal Measurements

Measurements of the coccyx are rarely taken or used.

11.2.3 Coccygeal Nonmetric Traits

- **Number of coccygeal vertebrae**: The number of coccygeal vertebrae is variable (usually 3–5). In rare cases, no coccygeal vertebrae are present, a situation called **coccygeal agenesis**.
- **Fusion with sacrum**: In older individuals, the coccyx may fuse (or synostose) with the sacral apex. Scheuer and Black (2000) note that sacrococcygeal fusion is more common in males.

11.3 Os Coxae (vav–11.12)

11.3.1 Anatomy

Unlike many bones that earned their names due to perceived similarities with common objects, the os coxae resembles no common object and thus has earned the informal name **innominate**—the "bone with no name." The os coxae differs in males and females, with its anatomy representing a compromise between the demands of locomotion and birthing. The os coxae is a part of the bony pelvis and is formed ontogenetically from three different parts, the **ilium**, **ischium**, and **pubis**, that fuse in early adolescence. Anatomical orientation of the os coxae is accomplished by placing the hip socket laterally and the ilium superiorly; this allows the plane of the **pubic symphysis** (the only place where right and left os coxae nearly meet) to define the sagittal plane.

The features identified here occur on both the surfaces and the edges of the os coxae. Many of the features are visible from different views of the bone. When correctly oriented, the anterior superior iliac spine should be in the same paracoronal plane as the most anterior point on the pubis.

a. The **ilium** is the thin, blade-like portion superior to the hip socket. The ilium is composed of a stout **body** close to the acetabulum and a large, flattened **ala** (or **blade**) flaring anteriorly, posteriorly, and laterally.

b. The **ischium** is the massive, blunt, posteroinferior part of the bone that one sits on. The ischium is composed of a **body** and two branches, or **rami**.

c. The **pubis** is the anteroinferior portion of the bone that approaches the opposite os coxae at the midline. Like the ischium, the pubis is composed of a **body** and two branches, or **rami**.

d. The **acetabulum** is the laterally facing, hemispherical hollow that forms the socket of the hip and articulates with the head of the femur. It has contributions from all three coxal elements: ilium, ischium, and pubis.

e. The **acetabular margin** is the prominent lateral edge of the acetabulum, interrupted by the acetabular notch.

f. The **acetabular fossa** is the nonarticular surface within the acetabulum. It is the attachment point for the *ligamentum teres* — a short, stout, round ligament that binds the femoral head to the depth of the acetabular fossa, guarding against femoral head dislocation but limiting femoral mobility.

g. The **acetabular notch** is the gap in the lunate surface at the margin of the obturator foramen. It is continuous with the acetabular fossa.

h. The **lunate surface** is the crescent-shaped articular surface within the acetabulum where the femoral head actually articulates.

i. The **supra-acetabular groove** is between the acetabular margin and the body of the ilium.

j. The **gluteal surface** is the outer surface of the iliac blade.

k. The **gluteal lines** are rough, irregular lines that demarcate the attachment of the *gluteal muscles* on the lateral surface of the ilium. They vary from prominent to imperceptible between individuals and across their paths. The *gluteus minimus muscle* originates between the inferior and anterior lines, and the *gluteus medius muscle* arises between the anterior and posterior lines. The *gluteus maximus muscle* originates posterior to the posterior gluteal line. The first two gluteal muscles, *minimus* and *medius*, are abductors and medial rotators of the femur at the hip, and the *gluteus maximus* is a lateral rotator, an extensor, and an abductor of the femur at the hip.

    1. The **inferior gluteal line** is a horizontal line just superior to the acetabulum.
    2. The **anterior gluteal line** is a line that curves posteroinferiorly through the fossa posterior to the iliac pillar.
    3. The **posterior gluteal line** is more vertically placed, near the posterior edge of the ilium.

l. The **sacropelvic surface** is the dorsal portion of the internal surface of the iliac blade. It faces the sacrum. The sacropelvic surface comprises:

    1. The **auricular surface** is the ear-shaped sacral articulation on the medial surface of the ilium. The auricular surface has two parts: the **cranial limb** and the **caudal limb**.
    2. The **iliac tuberosity** is the roughened surface just posterosuperior to the auricular surface. It is the attachment site for *sacroiliac ligaments*.

m. The **spina limitans** is the ridge, often appearing continuous with the superior margin of the cranial limb of the auricular surface, that separates the smooth iliac fossa from the more rugose sacropelvic surface.

n. The **iliac pillar** (or **acetabulocristal buttress**) is the bony thickening, or buttress, located vertically above the acetabulum on the lateral iliac surface. This pillar extends to the superior margin of the ilium.

o. The **tuberculum of the iliac crest** (or **iliac tubercle** or **cristal tubercle**) is the thickening at the superior terminus of the iliac pillar.

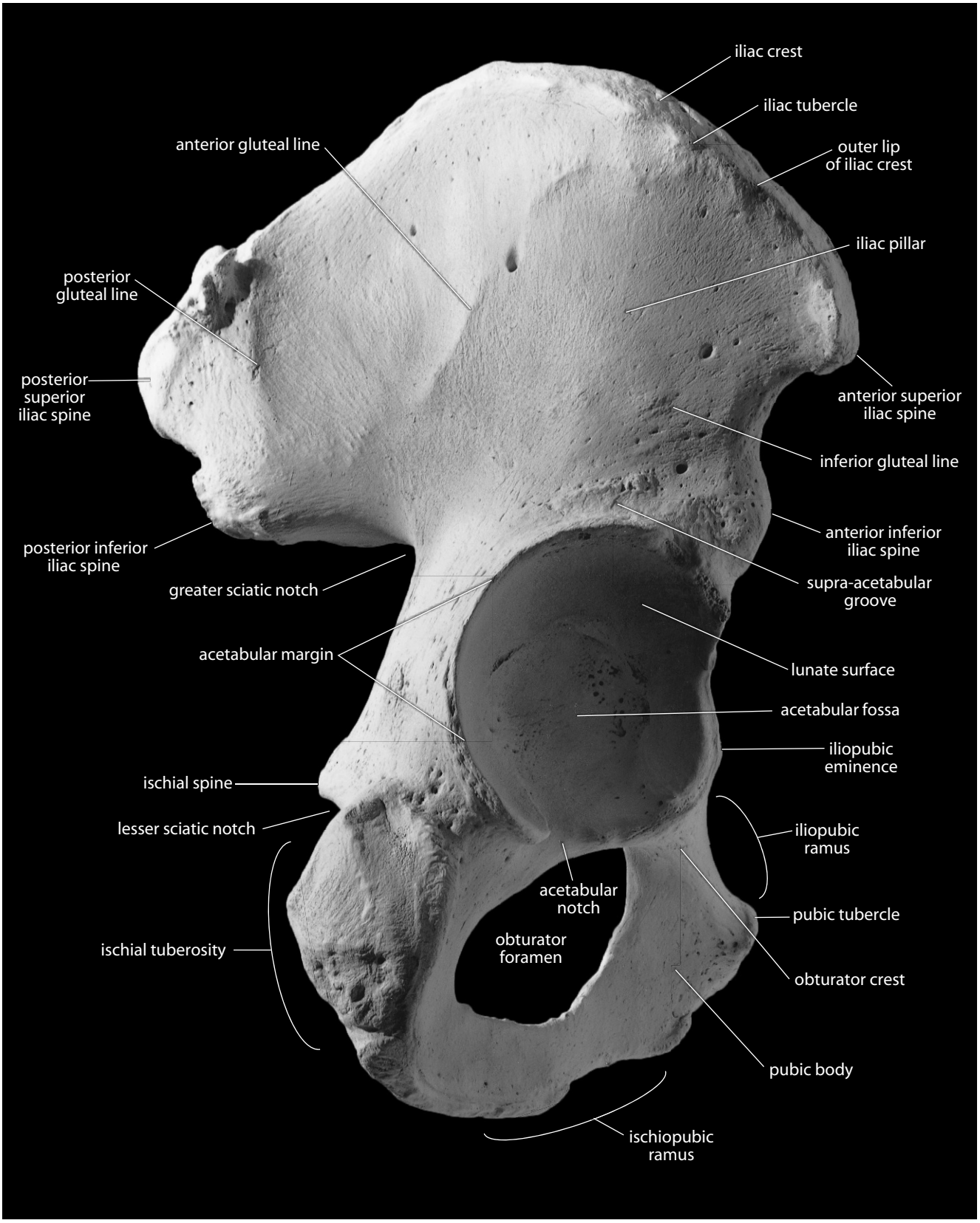

Figure 11.7 **Right os coxae, lateral.** Superior is up, anterior toward the right. Natural size.

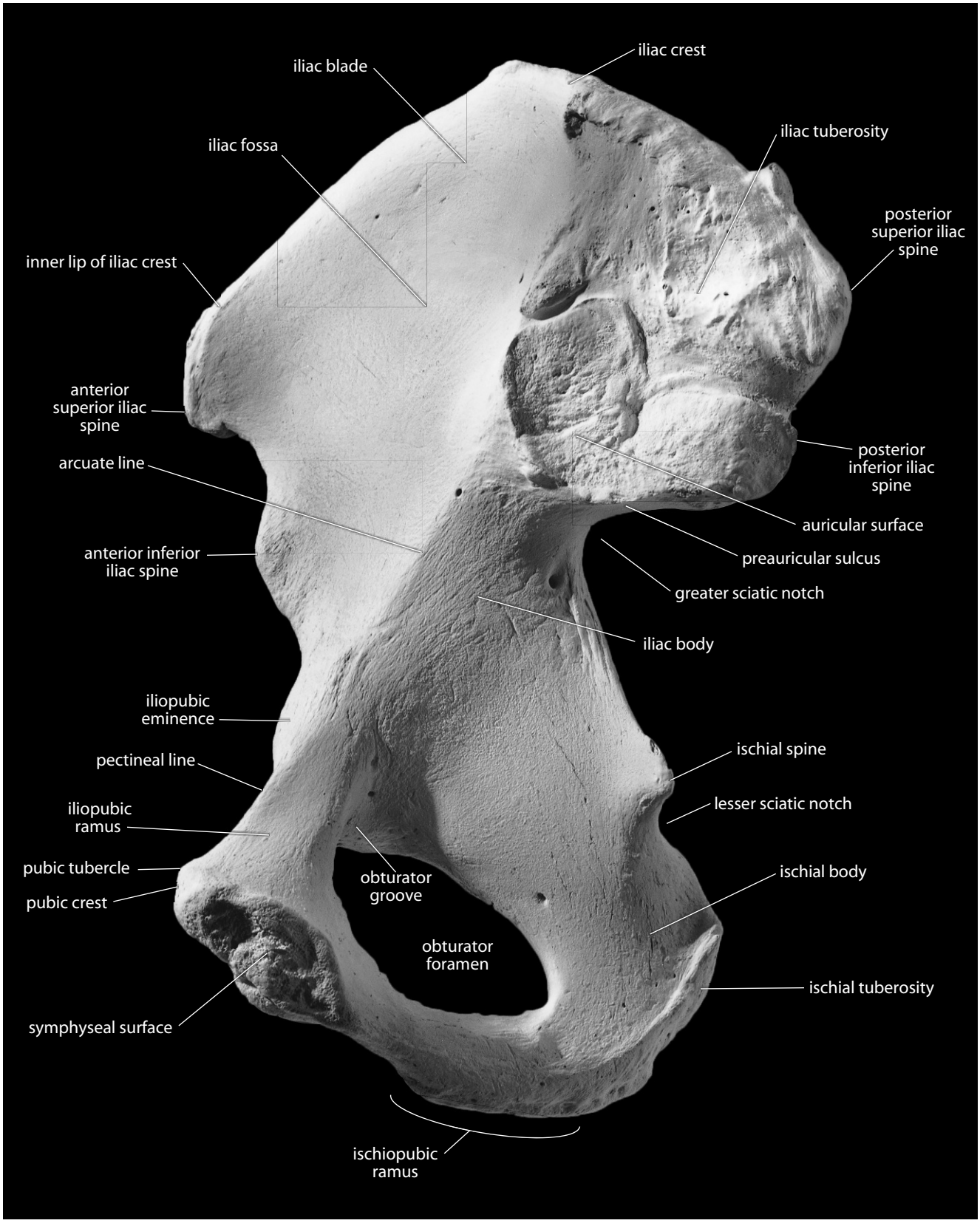

Figure 11.8 **Right os coxae, medial.** Superior is up, anterior toward the left. Natural size.

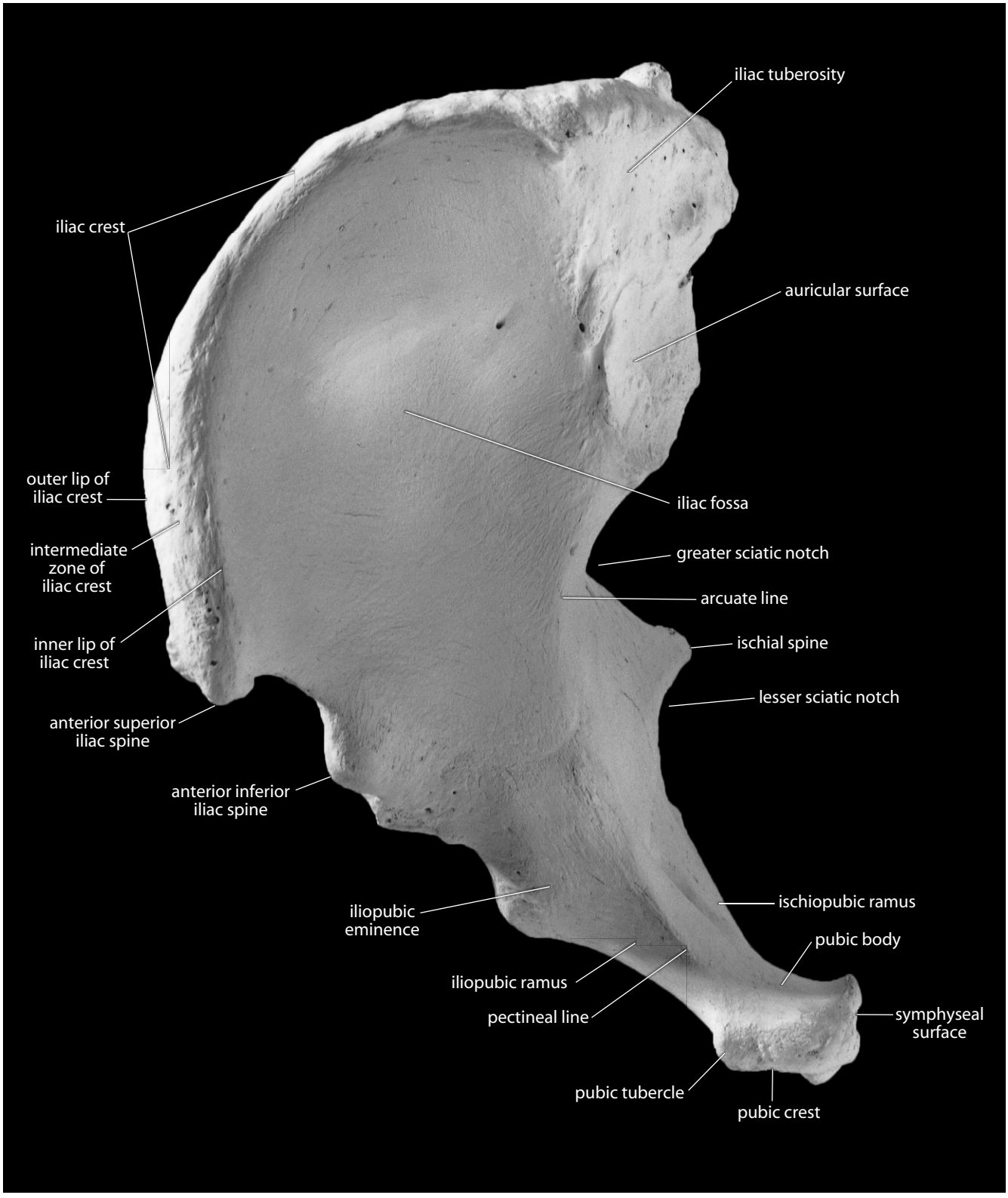

Figure 11.9 **Right os coxae, anterosuperior view.** Anterior is down. Natural size.

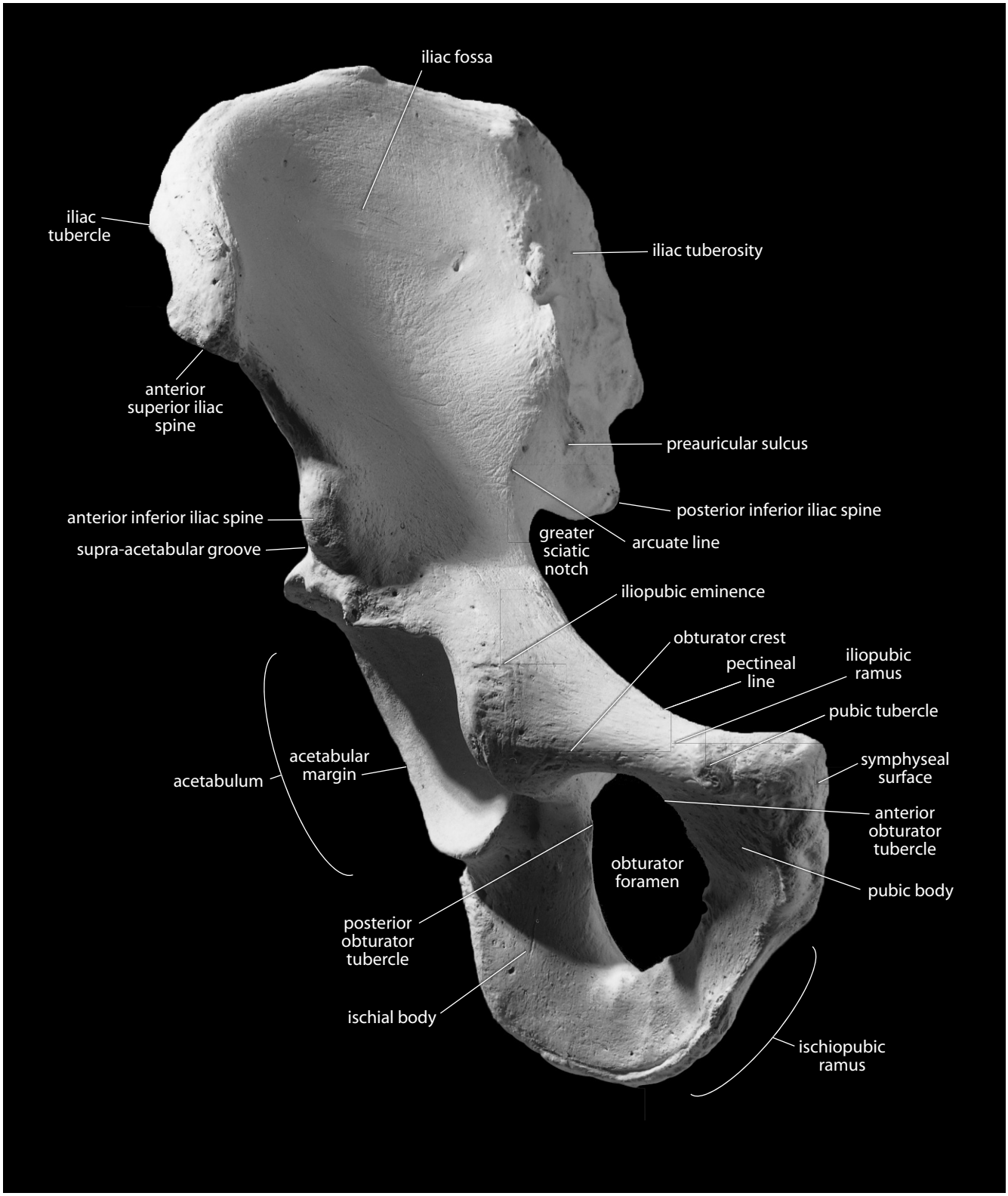

Figure 11.10 **Right os coxae, anterior.** Natural size.

p. The **iliac crest** is the superior border of the ilium. It is S-shaped when viewed superiorly. Many of the *abdominal muscles* originate on the crest.
    1. The **outer lip of the iliac crest** is the border that serves as the insertion of the *external oblique muscle*.
    2. The **inner lip of the iliac crest** is the ridge on the inner margin of the iliac crest that serves as the origin of the *transversus abdominis muscle*.
    3. The **intermediate zone** is the rugose area between the inner and outer lips of the iliac crest. The intermediate zone serves as the origin of the *internal oblique muscle.*

q. The **anterior superior iliac spine** is located at the anterior end of the iliac crest. It anchors the *sartorius muscle* and the *inguinal ligament*.

r. The **anterior inferior iliac spine** is a blunt projection on the anterior border of the os coxae, just superior to the acetabulum. It is the origin of the straight head of the *rectus femoris muscle,* a flexor of the thigh at the hip, and an extensor of the knee. Its lower extent serves as the attachment site for the *iliofemoral ligament*.

s. The **posterior superior iliac spine** is the posterior terminus of the iliac crest. It is an attachment for part of the *gluteus maximus muscle*, an extensor, lateral rotator, and abductor of the femur at the hip.

t. The **posterior inferior iliac spine** is a sharp projection just posteroinferior to the auricular surface. It partially anchors the *sacrotuberous ligament*, which serves to bind the sacrum to the os coxae.

u. The **preauricular sulcus** is a variable groove along the anteroinferior edge of the auricular surface.

v. The **greater sciatic notch** is the wide notch just inferior to the posterior inferior iliac spine. The *piriformis muscle*, a lateral rotator of the thigh at the hip, and the nerves leaving the pelvis for the lower limb pass through this notch. Cortical bone in the os coxae is thickest in this area.

w. The **ischial spine** for attachment of the *sacrospinous ligament* is located just inferior to the greater sciatic notch.

x. The **lesser sciatic notch** is the notch between the ischial spine superiorly and the rest of the ischium inferiorly. The *obturator internus muscle*, a lateral rotator and sometimes abductor of the femur at the hip, passes through this notch.

y. The **ischial tuberosity** is the blunt, rough, and massive posteroinferior corner of the os coxae. It anchors the extensor muscles of the thigh at the hip, including the *semitendinosus*, *semimembranosus*, *biceps femoris* (*long head*), and *quadratus femoris*.

z. The **iliac fossa** is the smooth hollow on the medial surface of the iliac blade.

aa. The **arcuate line** is an elevation that sweeps anteroinferiorly across the medial surface of the os coxae from the apex of the auricular surface toward the pubis.

ab. The **pectineal line** (or **pecten pubis**) is the anterior continuation of the arcuate line, often made sharper and more prominent by its role as the origin of the *pectineus muscle*.

ac. The **iliopubic** (or **iliopectineal**) **eminence** marks the point of union of the ilium and the pubis just lateral to the arcuate line.

ad. The **pubic crest** is the crest that connects the pubic tubercle to the pubic symphysis, providing the origin for the *rectus abdominis muscle.*

ae. The **superior pubic** (or **iliopubic**) **ramus** spans the distance between the pubic body and the acetabulum.

af. The **ischiopubic** (or **inferior pubic**) **ramus** is the thin, flat bridge of bone connecting the pubic body to the ischial body.

ag. The **pubic tubercle** (or **spine**) is the prominent bump on the anterosuperior aspect of the pubic body. It serves to anchor the *inguinal ligament*.

ah. The **symphyseal surface** of the pubis is the near-midline surface of the pubis where the two ossa coxa most closely approach. In life, the right and left symphyseal surfaces are covered in hyaline cartilage, separated by fibrocartilage, and bound together by strong *pubic ligaments* to form the **pubic symphysis**.

ai. The **obturator foramen** is the large foramen encircled by the two pubic rami and the ischium. In life it is nearly occluded by the *obturator membrane*, with only the area of the obturator groove remaining open.

aj. The **obturator crest** (or **ventral rim**) is the inferior margin of the anterolateral superior pubic ramus. It serves as the origin of the *pubofemoral ligament.*

ak. The **anterior obturator tubercle** is a small projection on the margin of the obturator foramen, just anterior to the obturator groove.

al. The **posterior obturator tubercle** is a small projection on the margin of the obturator foramen adjacent to the acetabular notch.

am. The **obturator groove** (or **sulcus**) is the wide groove on the medial surface of the superior pubic ramus, at the superolateral corner of the obturator foramen. The *obturator vessels* and *nerve* pass through the *obturator canal*, which is roofed by this groove.

11.3.2 Growth (Figure 11.11)

There are three primary and five secondary centers of ossification in each os coxae. The ilium, ischium, and pubis form the primary centers, fusing through the acetabulum in the **triradiate suture**. The ilium has one secondary center at the anterior inferior spine and one across the iliac crest. The pubis has one center at the symphysis (the "ventral rampart"), and the ischium has one at the tuberosity that extends along the ischiopubic ramus. The eighth center ("os cotyledon") is located in the depth of the acetabulum.

11.3.3 Possible Confusion

- Fragmentary iliac blades might be mistaken for cranial or scapular fragments. The cranial bones are, however, of more uniform thickness. They have cortices of about equal thickness around the diploë.
- Scapular blades are thinner than iliac blades and display subscapular ridges.
- Fragmentary auricular areas could be mistaken for sacra, but in the latter bone there are attached sacral alae, and the adjacent surfaces have no evidence of sacroiliac roughening or sciatic notches.

11.3.4 Siding

When intact, the os coxae is easily sided because the pubis is anterior, the iliac crest is superior, and the acetabulum is lateral. When fragmentary, various parts of the os coxae can be sided as follows:

- For isolated pubic regions, the ventral surface is rough, the dorsal surface is smooth and convex, the symphysis faces the midline, and the superior pubic ramus is more robust than the ischiopubic ramus.
- For isolated ischial regions, the thicker ramus faces the acetabulum. The thinner ramus is therefore anteroinferior. The surface of the ischial tuberosity faces posterolaterally.

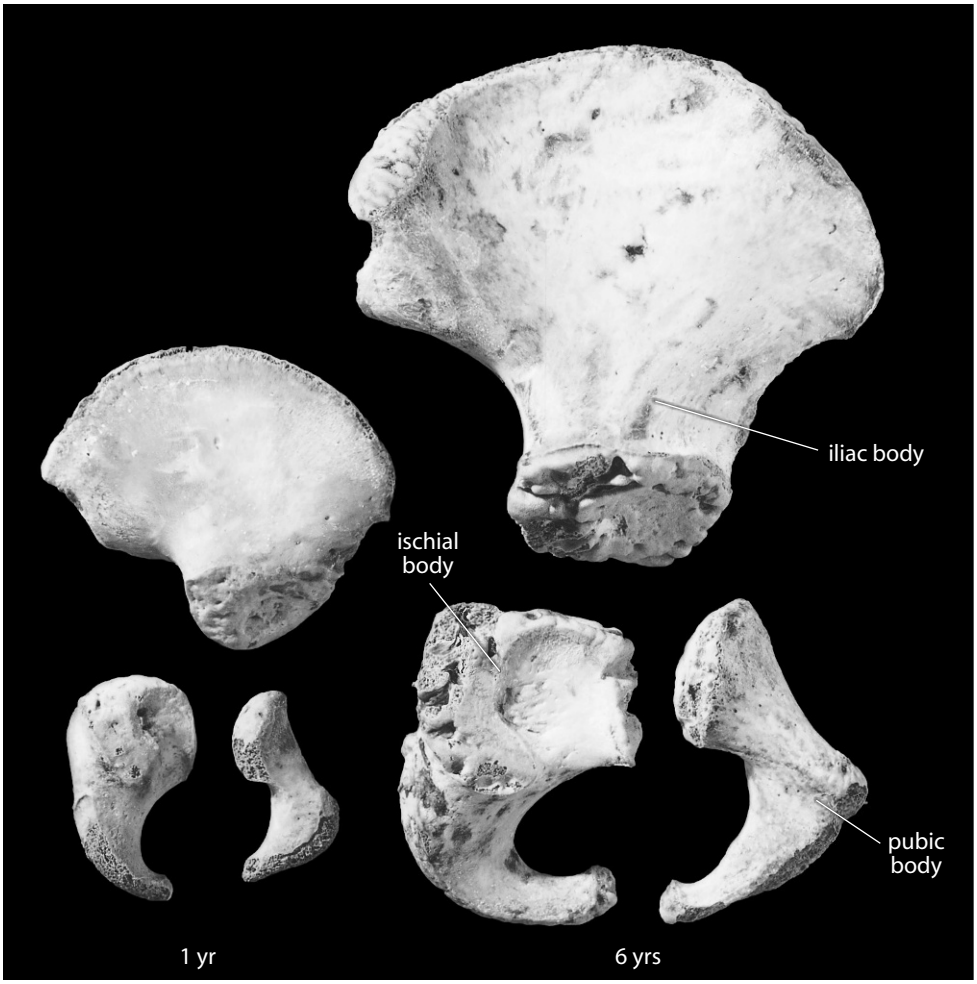

Figure 11.11 **Os coxae growth.** Natural size. The three elements of the os coxae, shown here in lateral view, are from a one-year-old child *(left)* and a six-year-old child *(right)*.

- For isolated iliac blades, the iliac pillar is lateral and is anteriorly displaced. The auricular surface and related structures are posterior and medial.
- For isolated iliac crests, the iliac tubercle is anterior and lateral, and the lateral surface anterior to it is more concave than the surface posterior to it. The crest sweeps posteromedially from this point until it reaches the level of the anterior edge of the auricular surface and turns laterally.
- For isolated acetabula, the acetabular notch is inferior and faces slightly anteriorly. The inferior end of the 'c' made by the lunate surface is broader and more blunt than the superior end. The ischial ramus is posterior, and the superior pubic ramus is anterior. The ilium is superior.
- For isolated auricular surfaces, the auricular surface is posterior on the ilium and faces medially. Its apex points anteriorly, and the roughened surface for the sacroiliac ligaments is posterosuperior. The greater and lesser sciatic notches are posteroinferior.

11.3.5 Coxal Measurements (Figure 11.12)

Measurements of the os coxae are used in formulas for determination of sex and age, and locomotor and obstetric biomechanics, among others.

1. **Os coxae height** (Buikstra and Ubelaker, 1994: 82, #56): Using either a large sliding caliper or an osteometric board, determine the maximum distance between the iliac crest and the ischiopubic ramus.
2. **Superior iliac breadth** (also **os coxae breadth**) (Martin, 1928: 1033, #12; Buikstra and Ubelaker, 1994: 82, #57): Using either a sliding caliper or an osteometric board, measure the maximum distance between the anterior and posterior superior iliac spines.
3. **Immature iliac breadth** (Buikstra and Ubelaker, 1994: 46, #11a): Open the sliding caliper, place the stationary jaw on the unfused anterior superior iliac spine, and carefully narrow the caliper until the second jaw contacts the most distant point on the posterior superior iliac spine.

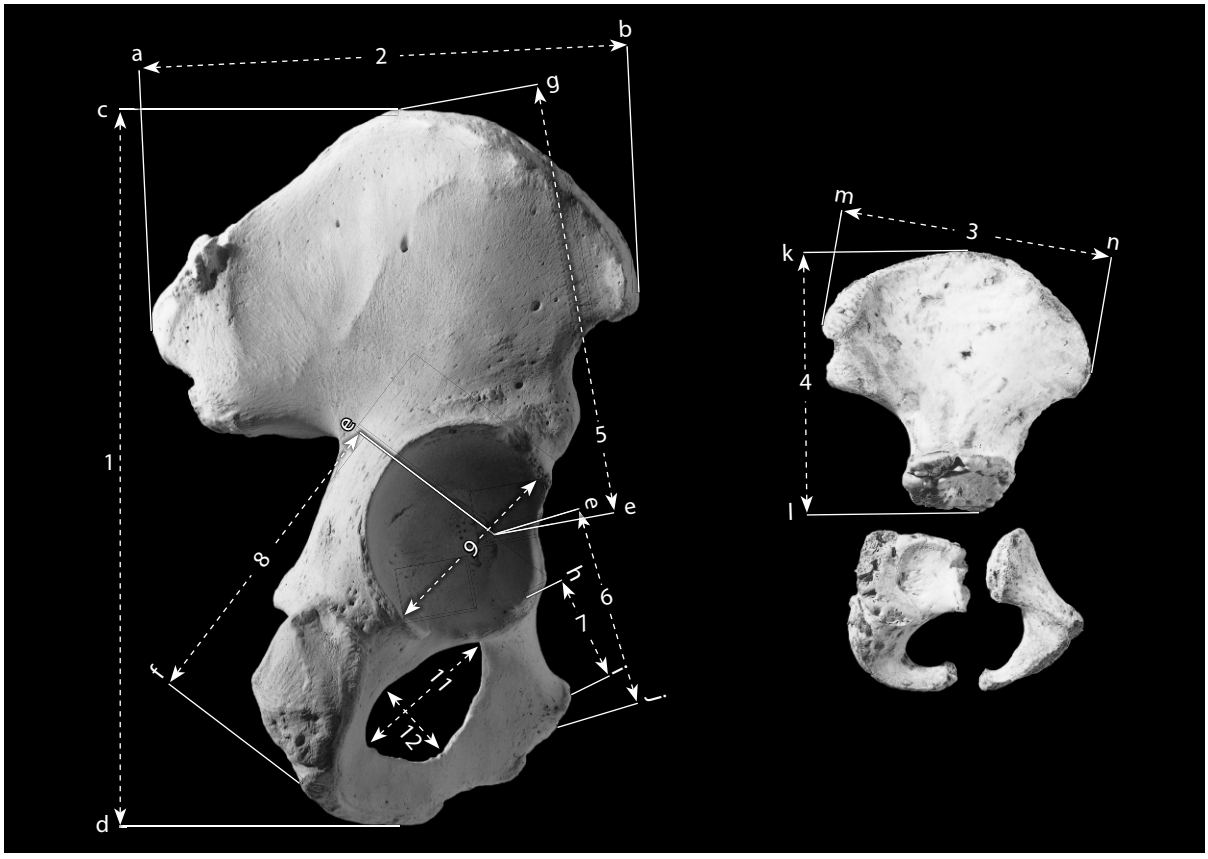

Figure 11.12 **Os coxal measurements.** One-half natural size.
Locations: a) point on the posterior superior iliac spine farthest from 'b'; b) point on the anterior superior iliac spine farthest from 'a'; c) point on the iliac crest farthest from 'd'; d) point on the ischium farthest from 'c'; e) point on the superior margin of the acetabular notch closest to the triradiate suture; f) point on the ischium farthest from 'e'; g) point on the iliac crest farthest from 'e'; h) point on the lunate surface closest to the pubic symphysis; i) superiormost point on the pubic symphysis; j) point on the pubis farthest from 'e'; k) point on the ilium farthest from 'l'; l) point on acetabular extremity closest to the center of the triradiate suture; m) point on unfused posterior superior iliac spine farthest from 'n'; n) point on unfused anterior superior iliac spine farthest from 'm'.
Measurements: 1) os coxae height; 2) superior iliac (or os coxae) breadth; 3) immature iliac breadth; 4) immature iliac height; 5) iliac length; 6) pubic length; 7) acetabulosymphyseal length; 8) ischial length; 9) acetabular height; 11) obturator foramen length; 12) obturator foramen breadth.

4. **Immature iliac height** (Buikstra and Ubelaker, 1994: 46, #11b): Open the sliding caliper, place the stationary jaw on the midpoint of the unfused iliac crest, and carefully narrow the caliper until the second jaw contacts the most distant point on the acetabular extremity.
5. **Iliac length** (or **height**) (Martin, 1928: 1032, #9): Spread the sliding caliper fully open, and place the stationary jaw of the caliper at the point along the superior margin of the acetabular notch closest to the center of the triradiate suture. Carefully narrow the caliper until the second jaw contacts the most distant point on the iliac crest.
6. **Pubic length** (Martin, 1928: 1033, #17; Buikstra and Ubelaker, 1994: 82, #58): Spread the sliding caliper fully open, and place the stationary jaw of the caliper at the point along the superior margin of the acetabular notch closest to the center of the triradiate suture. Carefully narrow the caliper until the second jaw contacts the most distant point on the pubic body.
7. **Acetabulosymphyseal length** (McCown and Keith, 1939): Open the sliding caliper, place the stationary jaw on the point on the lunate surface closest to the pubic symphysis, and carefully narrow the caliper until the second jaw contacts the superiormost point on the pubic symphysis.
8. **Ischial length** (Martin, 1928: 1033, #16; Buikstra and Ubelaker, 1994: 82, #59): Spread the sliding caliper fully open, and place the stationary jaw of the caliper at the point along the superior margin of the acetabular notch closest to the center of the triradiate suture. Carefully narrow the caliper until the second jaw contacts the most distant point on the ischium.
9. **Acetabular height** (Martin, 1928: 1033, #22): Using the inside diameter jaws of a sliding caliper, place the stationary jaw on the edge of the lunate surface (not the acetabular margin) immediately beneath the anterior inferior iliac spine. Carefully spread the caliper until the second jaw contacts the most distant point on the lunate surface.
10. **Acetabular depth** (Trinkaus, 2003: 4): Using a coordinate caliper placed at the same two points as used for acetabular height, determine the maximum depth of the acetabular fossa.
11. **Obturator foramen length** (Martin, 1928: 1033, #20): Using the inside diameter jaws of a sliding caliper, place the point of the stationary jaw in the middle of the obturator groove and carefully spread the caliper until the second jaw contacts the most distant point on the inferior margin of the obturator foramen.
12. **Obturator foramen breadth** (Martin, 1928: 1033, #21): Using the inside diameter jaws of a sliding caliper, measure the greatest breadth of the obturator foramen perpendicular to obturator foramen length.

11.3.6 Coxal Nonmetric traits

- **Accessory hip and sacral facets**: The sacrum and ilium may articulate — and form articular facets — at locations other than the auricular surfaces. These facets will always be dorsal to the auricular surfaces. Usually scored as 0 (absent) or 1 (present).
- **Acetabular crease**: Occasionally a groove, crease, or other surface feature penetrates the acetabular lunate surface from the superior margin of the acetabular notch near the trace of the triradiate suture. Usually scored as 0 (absent), 1 (notch), 2 (pit), 3 (groove), 4 (fold), or 5 (other).
- **Preauricular sulcus**: A variable groove, just inferior to the caudal limb of the iliac auricular surface, is observed in some individuals — usually, but not exclusively, in females. Usually scored as 0 (absent), 1 (groove of pregnancy), or 2 (groove of ligament).
- **Underdeveloped acetabulum**: The acetabulum is unusually shallow; present from *in*

utero and often linked to congenital hip dislocation. Usually scored as 0 (absent) or 1 (present).

- **Dorsal pitting**: On the pelvic (superodorsal) surface of the pubic body, eroded areas of bone can be observed in some individuals — usually, but not exclusively, in females. Usually scored as 0 (absent), 1 (small), 2 (medium), or 3 (large).

11.4 Pelvis (Figures 11.13–11.14)

Much like the skull, the pelvis is a complex system that needs to be considered as a unit — its shape, orientation, and function are not as apparent when viewed as a set of isolated constituent elements.

The shape of the articulated pelvis is a hybrid one: it forms both a basin and a canal. The division between these shapes is the **pelvic brim**, the angulated but dull transition between the "false" pelvis above (the basin) and the "true" pelvis below (the canal).

The pelvis is acutely inclined with respect to the pelvic brim. The angle between the brim and a horizontal reference plane (**pelvic inclination**: see Figure 11.14) is usually around 65° (Dauber and Feneis, 2007). A handy way to quickly place the pelvis in approximate anatomical position is to hold the pelvis with the sacrum positioned posteriorly and the sacral promontory facing superiorly. Then imagine a transverse axis passing through right and left auricular surfaces, and rotate the pelvis about this axis (lowering the pubis) until the pubic tubercles and the anterior superior iliac spines are in the same vertical plane (Figure 11.14).

The hominid pelvis is an example of the elegant evolutionary compromises made in biological form as the result of multiple competing selective pressures. The selective pressures on the pelvis are numerous and varied, but two of the most important factors in humans are these:

- Obstetrics: the pelvis must be large enough (and/or pliant enough) to allow a large-brained full-term fetus to successfully navigate the birth canal (if not, the condition is called cephalopelvic disproportion. This was, until recent history, a leading cause of both maternal and fetal mortality).
- Locomotion: the pelvis must anchor the muscles used to stabilize the trunk during bipedal walking.

11.4.1 Anatomy

a. **Pelvic surface** is the term for any surface of any pelvic bone that faces the pelvic cavity.
b. The **pelvic cavity** is the space below the abdomen that is defined by the pelvic bones.
c. The **pubic arch** is located immediately inferior to the pubic symphysis and is formed by the paired ischiopubic rami. The breadth of the pubic arch is measured as the subpubic angle.
d. The **greater** (or **false**) **pelvis** is that portion of the pelvic cavity above the linea terminalis and between the alae of the ilium.
e. The **lesser** (or **true**) **pelvis** is the portion of the pelvic cavity below the linea terminalis.
f. The **linea terminalis** is the pronounced line separating the greater and lesser pelves, formed by the sacral promontory, the arcuate line, the pectineal line, and the pubic crest.
g. The **iliopectineal line** is that part of the linea terminalis formed by the arcuate line and the pectineal line.
h. The **pelvic inlet** is the plane defined by the linea terminales. The pelvic inlet is the first of three constrictions that a fetus must navigate during the birthing process.

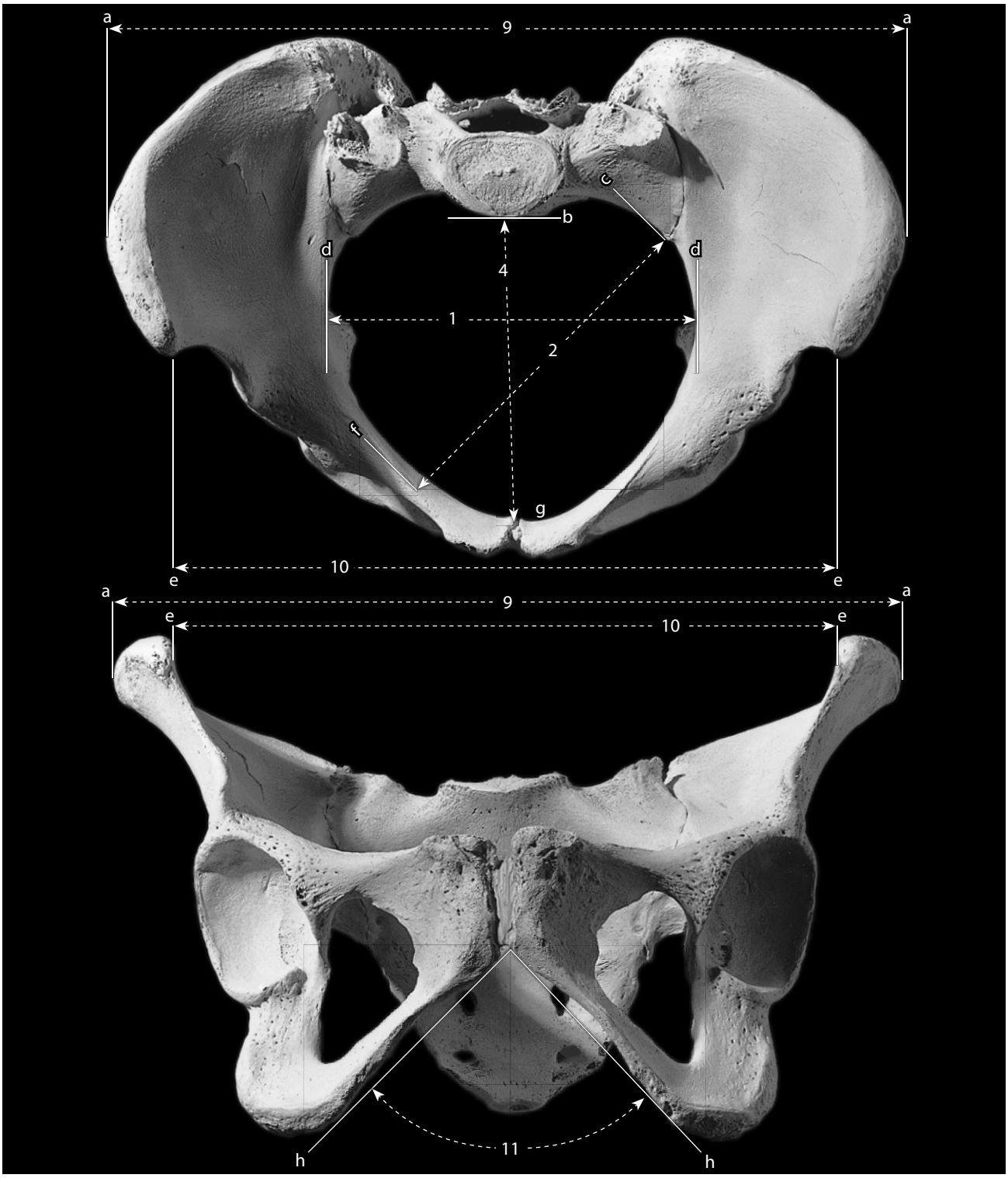

Figure 11.13 **Pelvic measurements.** One-half natural size.

Locations: a) lateralmost point on iliac crest; b) anteriormost point of sacral promontory; c) intersection of auricular apex and arcuate line; d) lateralmost point on arcuate line; e) anteroinferiormost point of anterior superior iliac spine; f) point on the iliopectineal line farthest from the contralateral 'c'; g) point on the pubic symphyseal margin closest to 'b'; h) line tangent to the inferior edge of the ischiopubic ramus.

Measurements: 1) transverse diameter; 2) oblique diameter; 4) true conjugate; 9) bi-iliac breadth (or intercristal distance or diameter); 10) interspinous distance (or diameter); 11) subpubic angle.

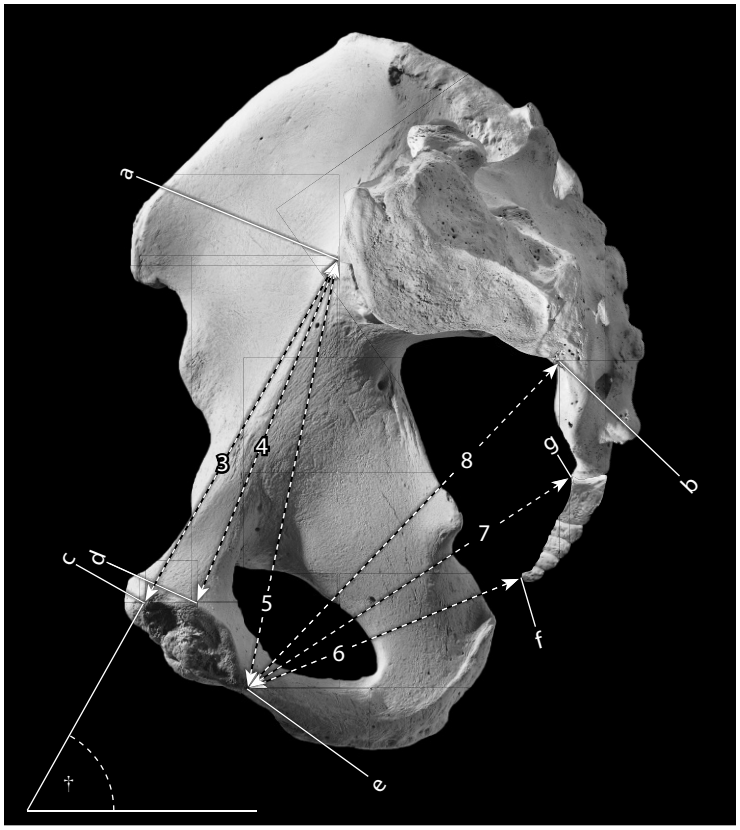

Figure 11.14 **Midline pelvic measurements.** Pelvic inclination (†) cannot be reliably measured on skeletal remains, but is usually about 65° in humans (Dauber and Feneis, 2007). One-half natural size.

Locations: a) intersection of auricular apex and arcuate line; b) midline point of the line of fusion between S-3 and S-4; c) anterosuperiormost point of symphyseal margin; d) point on symphyseal margin closest to 'a'; e) posteroinferiormost point of symphyseal margin; f) anteroinferiormost point on coccyx; g) ventralmost point on border of coccygeal articulation.

Measurements: 3) anatomical conjugate; 4) true conjugate; 5) diagonal conjugate; 6) straight conjugate; 7) inferior sacropubic diameter; 8) median conjugate.

i. The **pelvic outlet** is the plane defined by the ischiopubic rami, the ischial tuberosities, and the tip of the coccyx.

11.4.2 Pelvic Measurements (Figures 11.13–11.14)

Measurements of the pelvis are used in biomechanical analyses of locomotion, determinations of trunk shape, posture, and climatic adaptation, and in obstetric determinations like cephalopelvic disproportion.

1. **Transverse diameter** (Martin, 1928: 1034, #24): Using a deep-jawed sliding caliper, determine the greatest mediolateral distance between the right and left arcuate lines.
2. **Oblique diameter** (Martin, 1928: 1034, #25): Using a standard or deep-jawed sliding caliper, measure the distance from where the arcuate line meets the auricular surface of the ilium on one side to the farthest point on the arcuate line on the opposite side.
3. **Anatomical conjugate** (Dauber and Feneis, 2007: 64–65, #26): Using a standard or deep-jawed sliding caliper, determine the shortest distance between the sacral promontory and the anterosuperior margin of the pubic symphyseal surface.
4. **True conjugate** (Martin, 1928: 1033, #23): Using either a deep-jawed or offset-jaw caliper, determine the shortest distance between the sacral promontory and the posterosuperior margin of the pubic symphyseal surface.

5. **Diagonal conjugate** (Martin, 1928: 1034, #23(2)): With a sliding caliper equipped with at least one outside point extension, place the point extension on the posteroinferiormost point of the symphyseal margin, and determine the shortest distance to the sacral promontory. A difficult measurement to take without an extended-point caliper.
6. **Straight conjugate** (Martin, 1928: 1034, #26(1)): Using a deep-jawed sliding caliper, measure the distance from the tip of the coccyx to the inferiormost point of the pubic symphyseal margin.
7. **Inferior sacropubic diameter** (Martin, 1928: 1034, #26): Using a deep-jawed sliding caliper, measure the distance from the ventralmost point on the border of the coccygeal articulation to the inferiormost point of the pubic symphyseal margin.
8. **Median conjugate** (Dauber and Feneis, 2007: 64–65, #30): Using a deep-jawed sliding caliper, determine the minimum distance between the S-3/S-4 line of fusion and the inferiormost point of the pubic symphyseal margin.
9. **Bi-iliac breadth** (or **intercristal distance** or **diameter**) (Martin, 1928: 1032, #5): Using an osteometric board or large sliding caliper, measure the maximum distance between right and left iliac crests while the pelvic bones are held in articulation (there should be a gap of up to a centimeter between symphyseal surfaces to account for the hyaline cartilage and fibrocartilage of the living symphysis.
10. **Interspinous distance** (or **diameter**) (Martin, 1928: 1032, #5(1)): Using a spreading or sliding caliper, determine the distance between the anteroinferiormost points of both anterior superior iliac spines. As with bi-iliac breadth, this measurement is most accurately determined while the pelvic bones are held together in proper articulation.
11. **Subpubic angle** (Martin, 1928: 1034–1035, #33): Using a protractor or goniometer, measure the angular distance between the lines that are tangent to the inferior edge of the ischiopubic rami. As with the previous two measurements, this metric is most accurately determined while the pelvic bones are held together in proper articulation.

11.5 Functional Aspects of the Pelvic Girdle

The human pelvis is the distinctive foundation for a unique locomotor mode among primates, habitual bipedality. As this locomotor mode was adopted over six million years ago, most muscle groups attached to the pelvis altered their function. The bony architecture of the pelvis shows the effects of these mechanical changes (Lovejoy, 1988).

The three axes and six possible directions of rotation at the hip joint are the same as those in the shoulder joint — abduction and adduction, medial and lateral rotation, and flexion and extension. Like the *deltoideus muscle* of the shoulder, the major hip abductors *gluteus medius* and *gluteus minimus* form a hood across the top of the joint. Pulling between the iliac blade and the femur's greater trochanter, these muscles perform the key role of stabilizing the pelvis and superincumbent trunk during walking. The largest muscle in the human body by mass, *gluteus maximus*, is defined as a hip extensor, and in humans this muscle's primary role is to keep the trunk from pitching forward during running. The forward swing of the leg during walking is produced by the *iliopsoas muscle*, and the leg is decelerated by the *hamstring muscles.* These and other muscles that control the movements of the hip joint take their origin from various surfaces and projections of the os coxae.